

CROMWELL

**Design of a three-high tube mill
for rolling seamless tubes**

Mechanical Engineering

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DESIGN OF A THREE-HIGH TUBE MILL FOR ROLLING
SEAMLESS TUBES

BY

JOHN CABELL CROMWELL
B. S. University of Illinois, 1886

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

MECHANICAL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1910 *m*

UNIVERSITY OF ILLINOIS
THE GRADUATE SCHOOL

May 12

1910

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

John Cabell Cromwell

ENTITLED The Design of a Three-High Tube Mill for Rolling
Seamless Tubes.

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Mechanical Engineer

G. A. Goodenough

In Charge of Major Work

G. A. Goodenough

Head of Department

Recommendation concurred in:

G. A. Goodenough
Edward C. Schmitt
Emil Berg

Committee

on

Final Examination

168709



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LIST OF DRAWINGS.

- No. E-3775,- General Drawing of Mill.
No. A-3776,- Sub-base for 13" & 7" Bearings for Main Gear Drive.
No. 3777,- Details of 7" Bearings for Main Gear Drive.
No. 3778,- Details of Sub-bases for Roll Housings & Tables.
No. 3779,- Details of Sub-bases for Pinion Housings & Tables.
No. A-3780,- Motor Sub-bases.
No. 3781,- Details of Main Gears.
No. 3782,- Details of Fly Wheel, Mill Pinions & Main Shafts.
No. 3783,- General Arrangement of 20" Three-high Roll Housing.
No. A-3784,- Details of 20" Three-high Roll Housing.
No. 3785,- Details of Chucks & Bearings for 20" Roll Housings.
No. 3786,- Cap & Screw-down Details for 20" Roll Housing.
No. A-3787,- 20" Three-high Pinion Housing.
No. 3788,- Details of Side Rods of Table with Separators.
No. 3789,- Separator at Mill End of Lifting Table.
No. 3790,- Details of Turned Machinery for Lifting Tables.
No. 3791,- Details of Turned Machinery for Lifting Tables.
No. 3792,- Details of Levers & Cranks,- Lifting Tables.
No. B-3793,- Details of levers & Links.
No. A-3794,- Levers and Cams for Lifting Tables.
No. 3795,- Shafting, Cranks & Gears for Lifting Tables.
No. B-3796,- Details of Levers & Shafting for Pusher.
No. 3797,- Details of Gear Covers.
No. A-3800,- Details of Mill Rolls, arranged for rolling 3" Tubes.
No. 3801,- Section of Passes of Mill for Rolling 3" Tubes.
No. 3802,- Cam Motion Diagram for Lifting Table.
No. 3803,- Motion Diagram for Entering Table.
No. 3804,- Motion Diagram of Delivery Table.
No. 5933,- Diagram of Levers for Lifting Table adjusted for 20" Diagram Rolls.
No. A-3838,- Foundation Plan for Mill.
No. 5856,- Details of Mandrels & Rolling Plugs for Mill Rolling 3" Tubes.
No. 2733,- Details of 13" Bearing for Main Shaft.
No. S-2635,- Diagram Illustrating Rolling of Tubes.

INTRODUCTION.

In the manufacture of seamless steel tubes in sizes ranging from 2" to 6" in diameter, it is customary to start with a solid rolled round bar of approximately the diameter of the finished tube and subject same to the following operations in order to produce the finished tube:-

Piercing,
Rolling,
Cold Drawing.

In case a hot finished tube is desired, the last named process of cold drawing is omitted, the tube being finished by the process of rolling supplemented in some cases by a smoothing process called reeling.

It is with the second step in the manufacture of seamless steel tubes, namely,- rolling, which the machine herewith described has reference.

The problem was to construct a mill of great capacity that will be operated without the employment of manual labor, thereby greatly reducing the cost of manufacture.

The style of mill selected to fulfill this object was the three-high type, which, while being in very common use in the rolling of all solid materials, has previously not been developed to much extent for rolling tubes, the two-high type with an excessive use of manual labor having been the type almost universally used.

The rough material upon which this rolling mill works consists of a rough pierced tube blank having an outside diameter somewhat larger than the finished tube and having a thickness of metal about $3/8$ ".

The average length of this tube blank is about 8 ft., and the work which the mill performs is to roll this into a smooth tube about 24 ft. long and having a thickness of the wall of about $1/8$ ".

In all tube rolling there is required a stationary plug located centrally between the working rolls over which the tube is forced by means of the friction between the rolls and the outside of the tube, the thickness of the metal being reduced by this action.

In this mill there are seven passes or sets of grooves, and the tables are so arranged as to handle the tube and the plug successively and automatically into the various rolling positions, also, turning the tube 90° between each pass as is necessary in this work.

The detail of the design of the machinery together with a description of the operation of same is the subject of this thesis.

GENERAL ARRANGEMENT.

The general arrangement of the mill is shown on drawing No. E-3775, which shows the mill complete with the tables located in the upper position for rolling the tube from right to left.

SIZE OF MILL.

The normal size of the mill is 20" with rolls 2 ft. 10 in. long in the body.

Detail of the rolls together with the passes in same arranged for rolling 3" tubes, is shown on drawing No. A-3800, and a section of the seven passes made in rolling same is shown on drawing No. 3801.

The rolls were made comparatively short for their diameter in order to do away with as much springing as possible during the rolling; also extra large necks are provided in order to make as rigid a mill as possible.

The rolls are made of sand cast iron which has the best surface for this work.

DRIVING MOTOR.

The mill is driven by a 300 H. P., 500 volt Compound wound, D. C. Westinghouse motor, having a speed varia-

tion from 345 to 500 r.p.m. This is connected to the mill by means of a pair of cut steel gears, shown on drawing No. 3781, having a speed ratio of 4.58 to 1, thereby driving the mill from 75.2 to 109.1 r.p.m.

The mill shows a friction load when running at 85 r.p.m. of from 50 to 100 amperes, and when rolling 3" tubes a load of 250 to 300 amperes.

FLY WHEEL

By the side of the pair of steel cut gears, above described, is located a fly wheel shown on drawing No. 3782, which is 19 ft. in diameter and weighs 48,000 lbs.

This wheel is sufficiently heavy to take care of all the shocks due to the entering and rolling of the tube, so that no perceptible change in speed is noticeable during the operation of the mill.

MAIN BEARINGS & SHAFTING.

The details of these bearings are shown on drawings Nos. A-3776, 3777, 3782 and 2733.

These bearings are very large and rigid, those on the motor shaft being ring oiled, while those on the fly wheel shaft are arranged so that suet with water can be used, which has proved to be the best lubricant upon this class of work.

MILL PINIONS & HOUSING.

The details of the mill pinions are shown on drawing No. 3782.

The teeth are made spiral and very short and stubby, which works best in this service. The curve of the teeth is a $22-1/2^{\circ}$ involute.

The necks of the pinions are extra long so as to provide long life to the bearings.

The pinion housing is shown on drawing No. A-3787, and is made of steel castings securely bolted together forming an entirely closed housing so that the pinions can be run in tar.

Ample provision is made for lubricating the necks of the pinions with suet and water, which is found to be the best for this service.

The pinion housing stands on a heavy sub-base, which is securely bolted to the foundation. This sub-base is shown on drawing No. 3779.

ROLL HOUSING.

The general arrangement of the roll housing is shown on drawing No. 3783, and the details of same together with bearings, caps, etc., upon drawings Nos. A-3784, 3785,

and 3786.

These housings with all bearing castings are made of steel, the bearings for the rolls proper being made of a combination of brass and babbitt.

The arrangement of the bearings is such that the middle roll is stationary and the adjustment of rolls is taken care of by moving either the bottom or top roll. The top roll is counter-balanced by springs. The arrangement of the bearings is such that when the piece is passing between the middle and bottom roll, that no load is transmitted to the bearing of the upper roll, thereby producing no undue friction and wear. Same is also true when the piece is passing between the middle and top roll, that no pressure is transmitted to the neck of the lower roll.

The cap is held down rigidly by keys. The design is exceedingly stiff and rigid, with a view of extreme rigidity combined with quickness of adjustment.

SUB-BASE CONSTRUCTION.

The roll housings, together with the bearings for the tables, are supported by a very heavy sub-base construction, shown in detail on drawings Nos. 3778, 3779 and A-3780.

The various parts of this sub-base are held in line by means of keys at right angles to each other and by shrunk

links, thereby forming practically one rigid member, which holds all the parts securely in line.

LIFTING TABLES.

The tables on each side of the mill are made of two 7" round steel bars having a cross-head at the housing end, which takes the thrust against the housing when the table is in the rolling position, and having an additional cross-head at the outer end to resist the tension of the mandrel bars during the process of rolling. This strain is of considerable magnitude, and when rolling 4" tubes the work of rolling over the plug produces a strain in the mandrel bar of 128,000 lbs.

The principal details of this table are shown on drawings Nos. 3788 and 3789.

OPERATION OF TABLE.

The table is operated through a series of levers, which obtain their motion by means of a crank driven through a train of gearing from two G. W. Crocker-Wheeler motors, each having a nominal rating of 75 H. P. These two motors are connected in series, using 500 volts D. C. The current consumed in moving the table is 400 amperes, and the time

consumed in either raising or lowering the table is two and one-half seconds.

The diagram of the motion of the table is shown on drawings Nos. 3802, 3803, 3804 and 5933.

Both tables have, in addition to a lifting motion, a reciprocating motion, the tables thereby stopping at different horizontal distances from the center of the rolls at the two ends of the stroke.

The entering table has in addition, a side motion, in order to pass the tube horizontally across the mill. This side motion is obtained by means of cams, shown on drawing No. 3802, located on the main oscillating shafts.

TURNING ARRANGEMENT.

As stated above, it is necessary when rolling tubes to turn them through an angle of 90° between each pass.

The details of the turning arrangement are shown on drawings Nos. 3789, 3790 and 3791, and the assembled view, showing the tube passing through same, is shown on diagram drawing No. S-2635.

The motion to operate the twistors is obtained through a series of levers and gears, which automatically rotate the twisting sleeves by means of motion obtained from raising and lowering the table.

PUSHERS.

In order to enter the tube in the rolls after the tables have moved same in line with the proper pass in the rolls, there is provided on each side of the mill a pusher that has fingers, which engage the end of the tube and pushes it into the rolls.

Each of these pushers is operated by a 48-A Westinghouse, series wound, 30 H.P. motor, connected by means of a train of gearing to a crank motion, which reciprocates the pusher by means of a series of levers, making an approximate straight line motion.

The details of the pusher are shown on drawings Nos. B-3796, A-3780 and 3788.

MANDRELS & PLUGS.

The mandrels and plugs required for rolling 3" tubes, are shown on drawing No. 5856.

The material of the plugs, which stand the excessive abrasion due to the rolling of the tube, is made of crucible steel castings, and the plugs are used in the rough without removing the scale.

The plug is fastened onto the mandrel bar by means of a short bolt, having a square screw thread, part of which is cut away so that it can be locked in position by the

movement of a third of a revolution.

WEIGHT.

The entire weight of the mill, exclusive of driving motor or rolls, is approximately 520,000 lbs.

FOUNDATIONS.

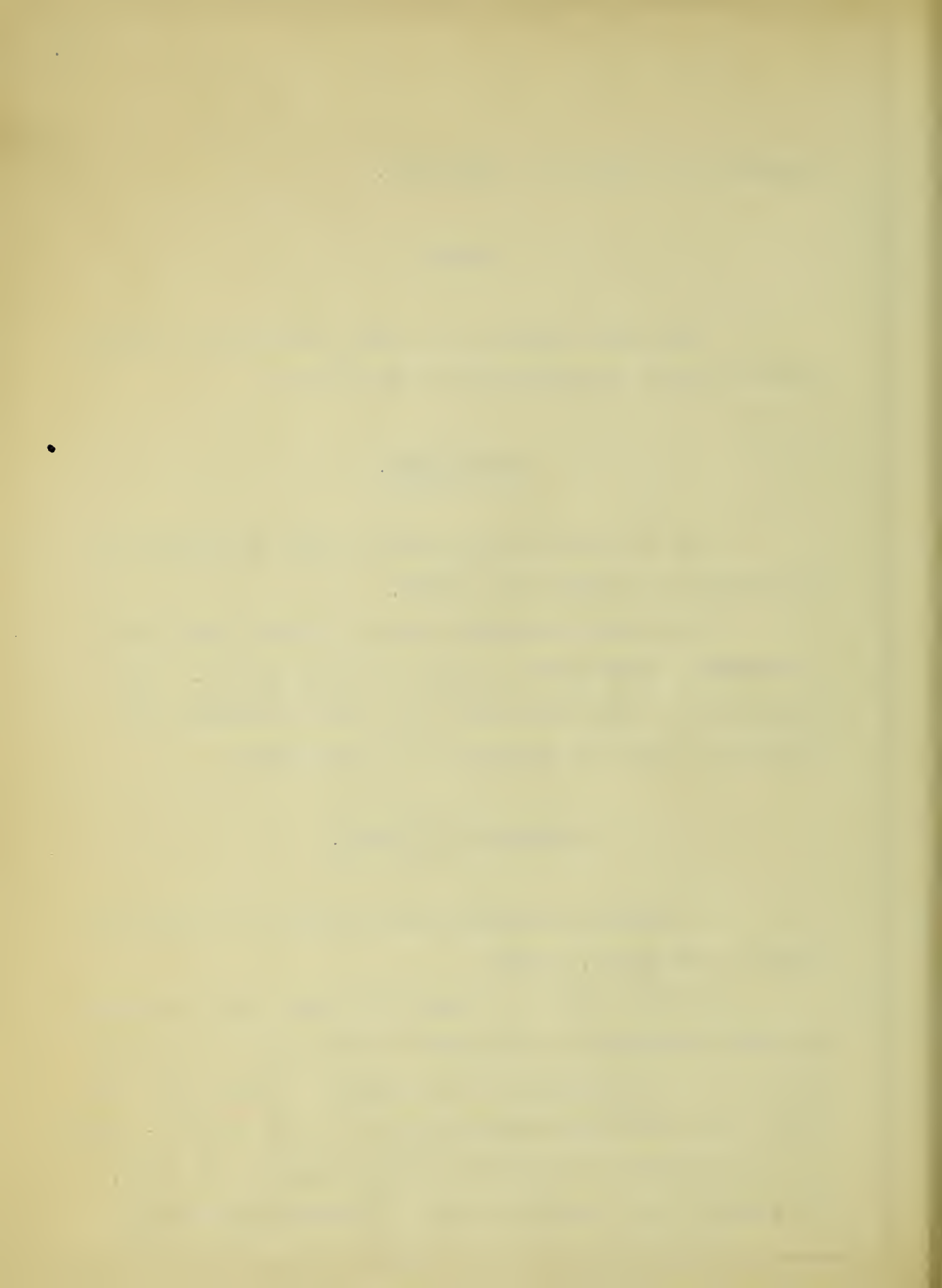
The foundation of the mill was made of concrete in accordance with drawing No. A-3838.

The concrete work was made of one part Atlas Portland cement, three parts sand and six parts gravel. The mixing was done by hand, and it was laid in sections, in horizontal layers not exceeding 6" in thickness.

OPERATION OF ROLLING.

A diagram illustrating the rolling of the tubes is shown on drawing No. S-2635.

The tube blank is brought while hot from the piercing mill and placed on the mandrel which stands in front of pass No. 1. This mandrel is then pushed forward until the plug on the end of same comes into the rolling position, which is in the center of the groove directly between the rolls. The pusher on the entering table is then advanced and the



blank is forced into the rolls when it is immediately gripped by same and rolled through its entire length, being received on a mandrel and held in line therewith by the receiving table.

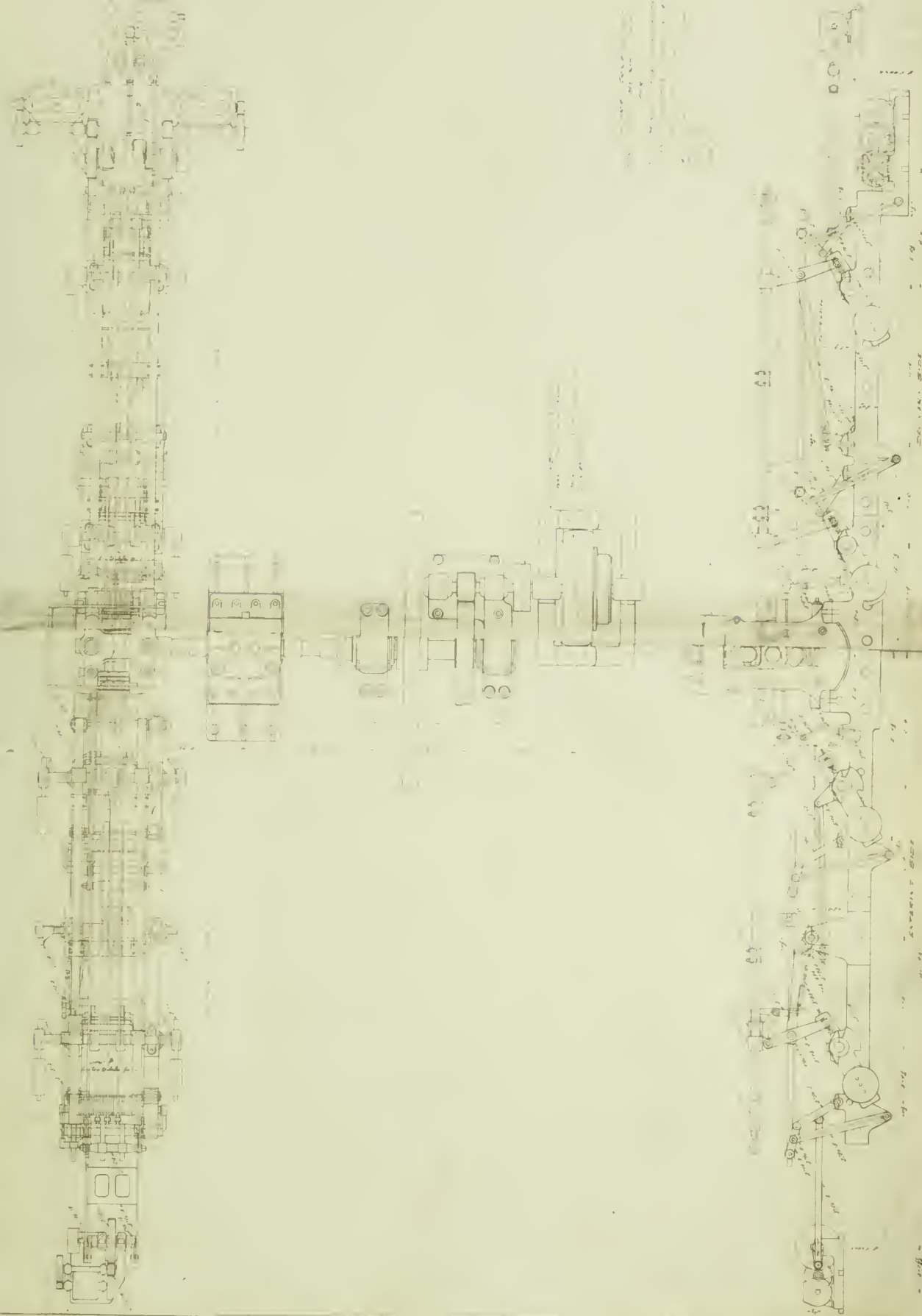
The tables are then raised to the upper position, during which time the tube blank is rotated 90° by means of the twister. It then stands in line with pass No. 2 and is ready to be rolled through this pass. The pusher on the delivery table is now advanced and the tube is rolled through this pass.

The same set of motions is repeated and the bar is successively passed through the remaining passes until it is delivered through pass No. 7, when the thickness of the wall is approximately $1/8"$.

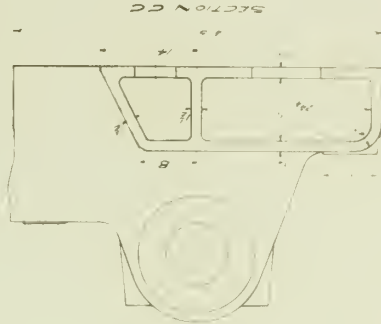
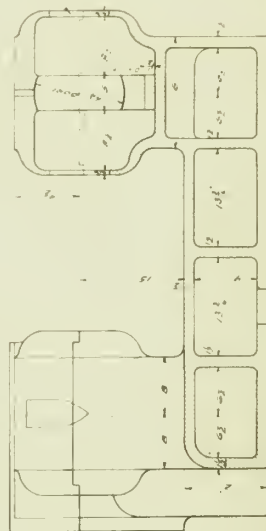
All the labor that is required beside bringing the tube blank to the mill and taking the finished tube away from it, is performed by one operator, who handles three electric switches, one for raising and lowering the table and two for operating the two pushers.

The nominal time of rolling a tube is one minute, and by making due allowance for all delays and the change of plugs, the mill should roll 500 tubes in a turn of twelve hours, or 1000 tubes per day of twentyfour hours.





SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
SECTION I-I
SECTION J-J
SECTION K-K
SECTION L-L
SECTION M-M
SECTION N-N
SECTION O-O
SECTION P-P
SECTION Q-Q
SECTION R-R
SECTION S-S
SECTION T-T
SECTION U-U
SECTION V-V
SECTION W-W
SECTION X-X
SECTION Y-Y
SECTION Z-Z



SECTION-B-B

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2-7.2

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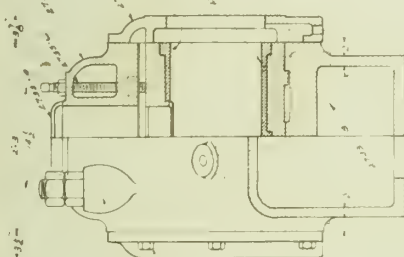
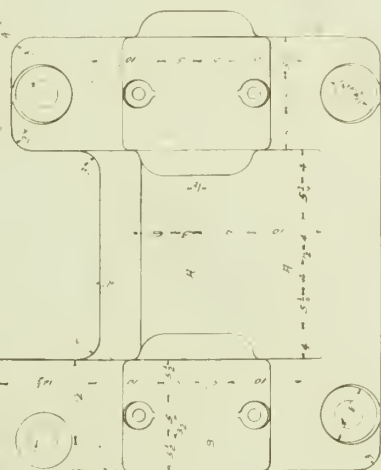
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TOP 2 DEEP FOR 1/2" CAP SCREWS

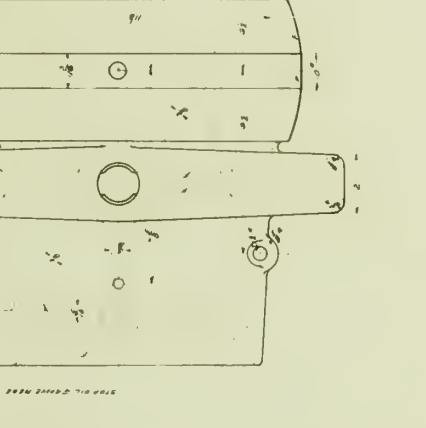
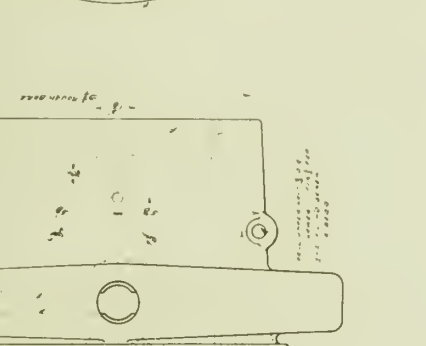
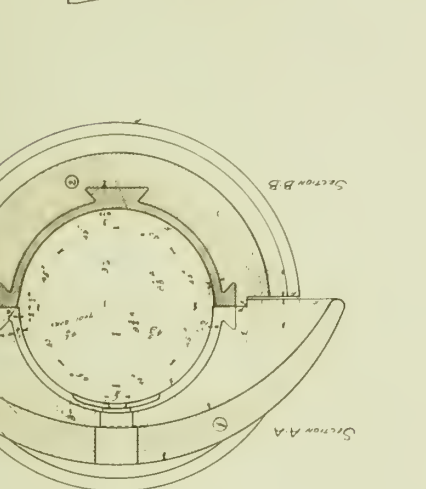
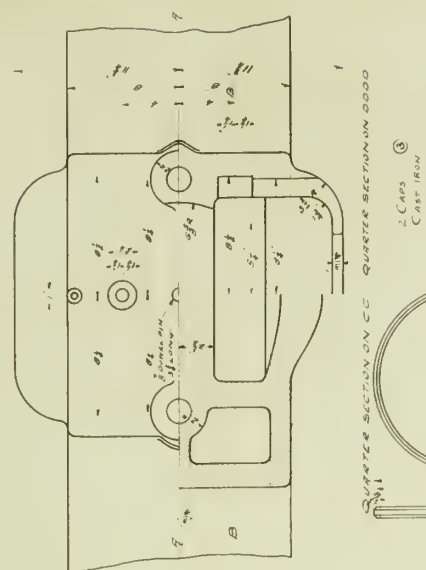
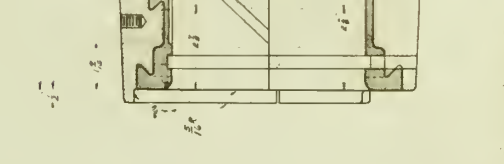
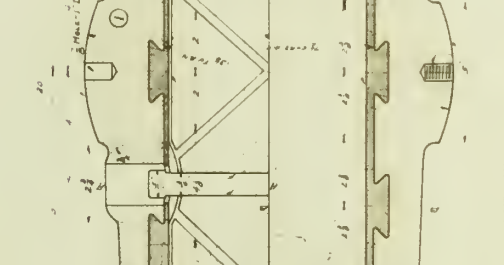
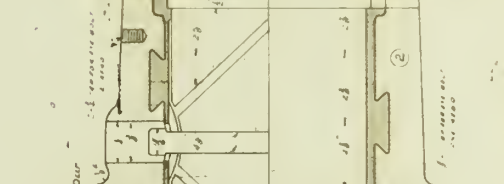
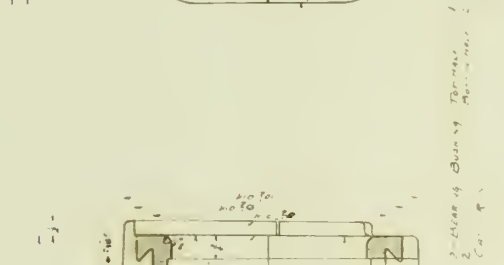
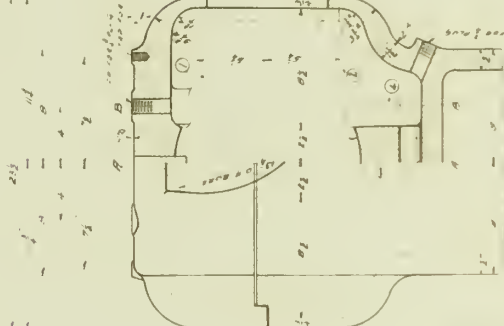
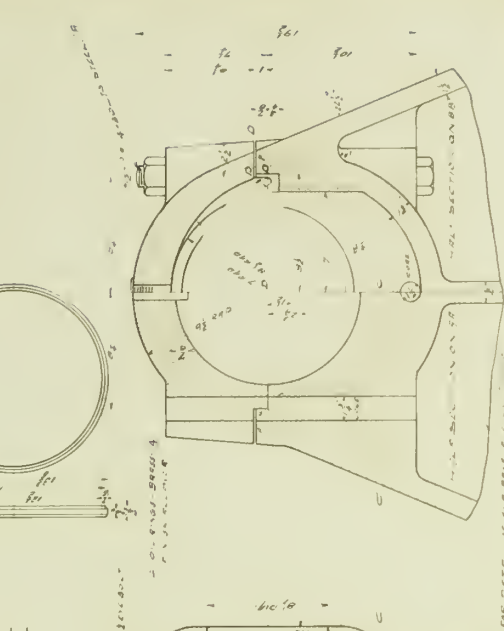
TOP 2 DEEP FOR 1/2" CAP SCREWS

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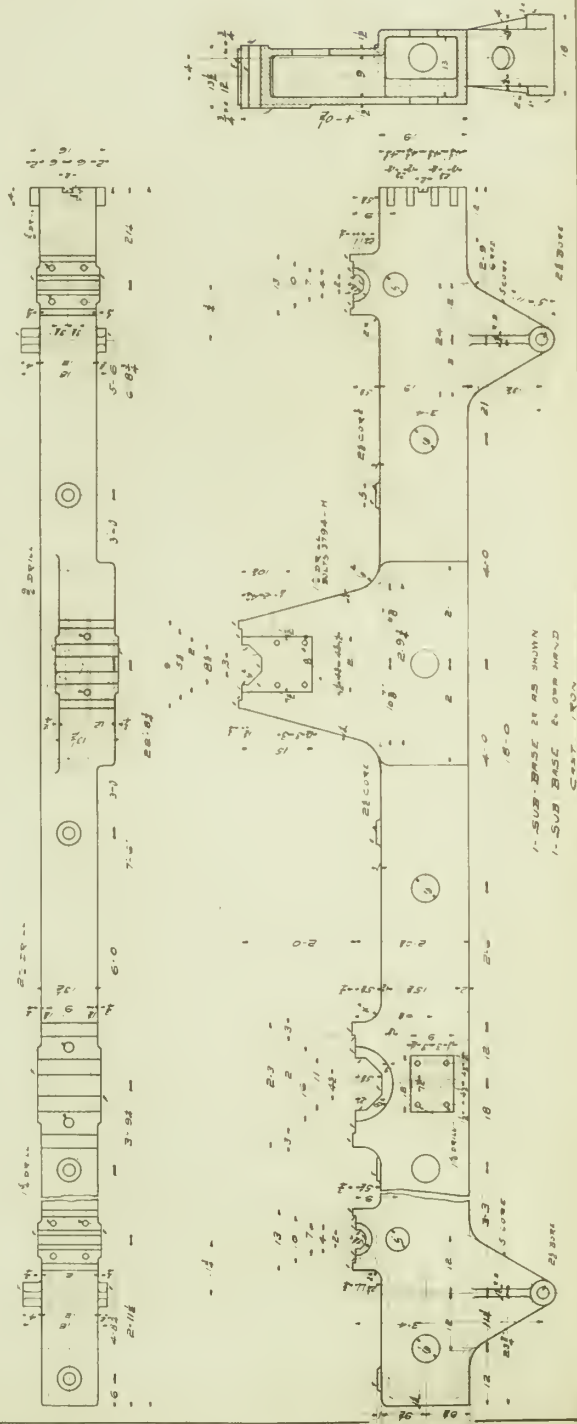
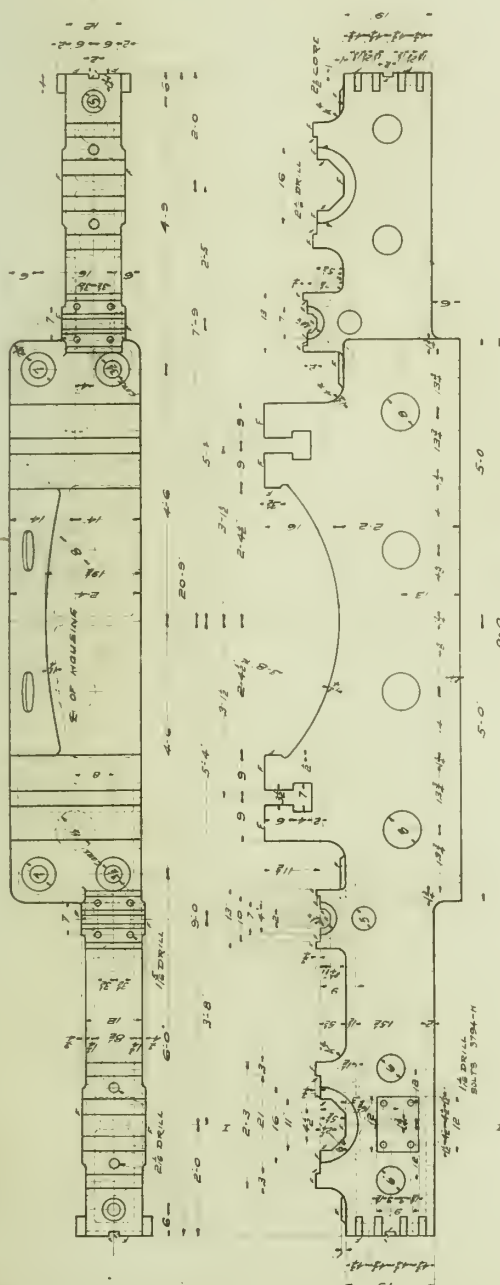
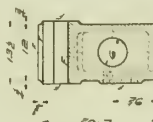
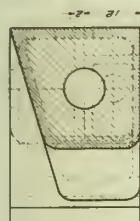
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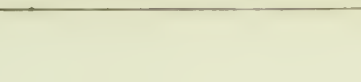
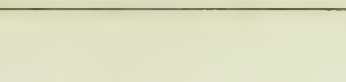
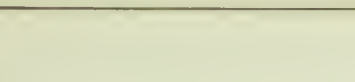
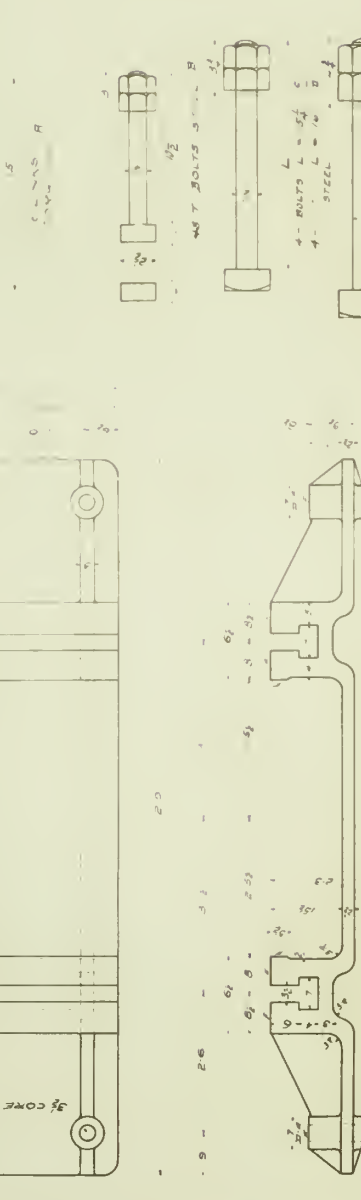
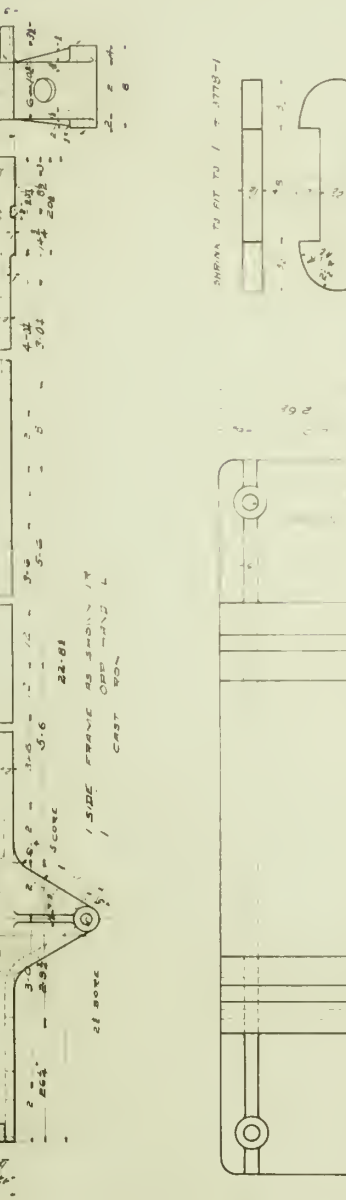
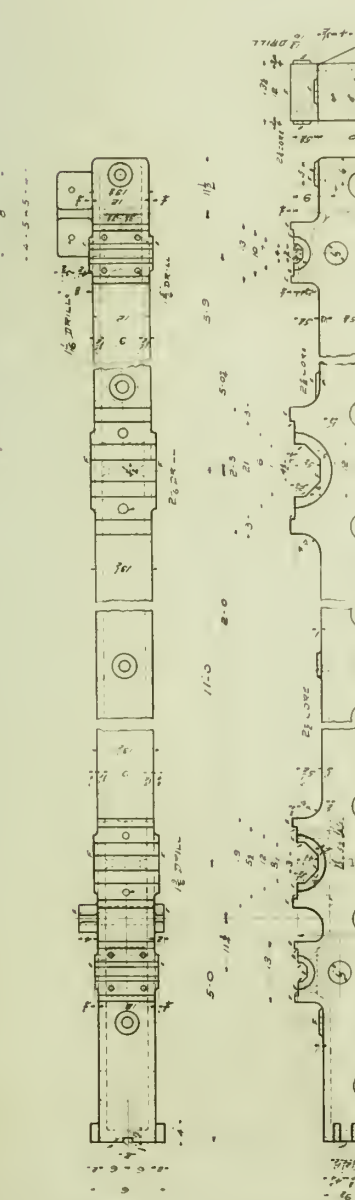
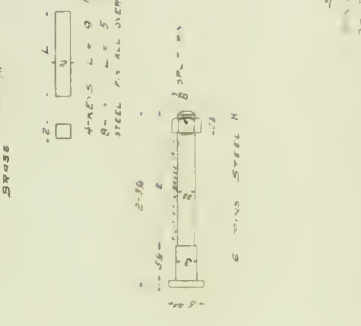
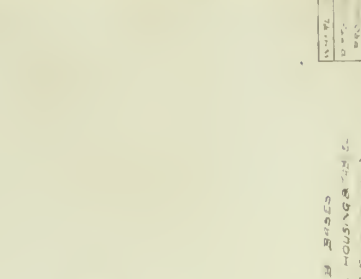
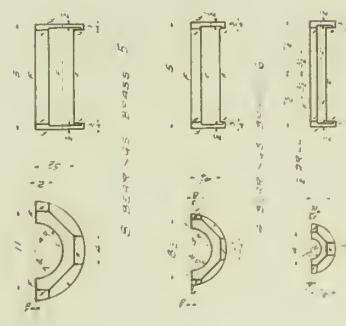
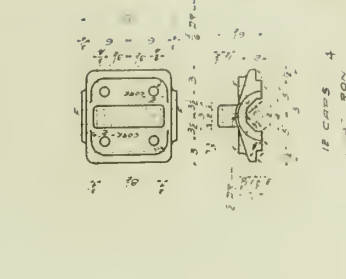
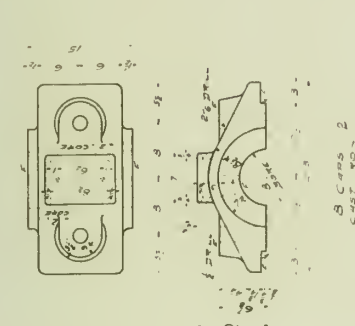
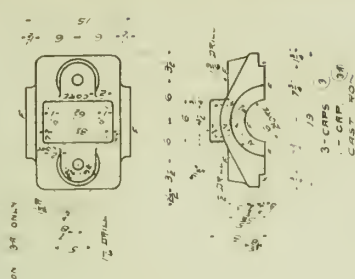
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Sketch of a geological feature, possibly a fault or fold, with labels 'S' and 'N' indicating orientation.

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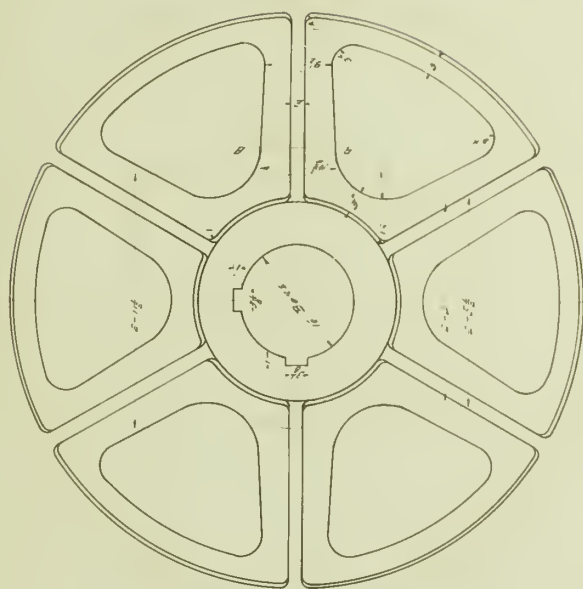
SUN BASES
FOLL HOUSING "6 TABLES
20 THREE HIGH TUBE MILL
THE GARRETT CROMWELL ENGINEERING CO
CLEVELAND OHIO
JULY - 7. 909
SCALE 1/8" = 1"







MINUTE SIZE SECTION ON LINE AA



7-50 02
7-3039 P. T. C. M. 2114

1. - UT 1044

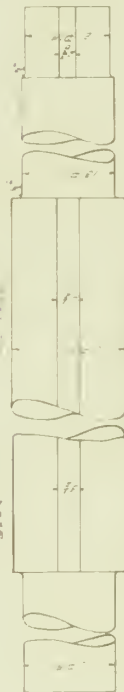
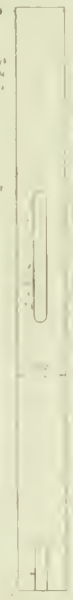
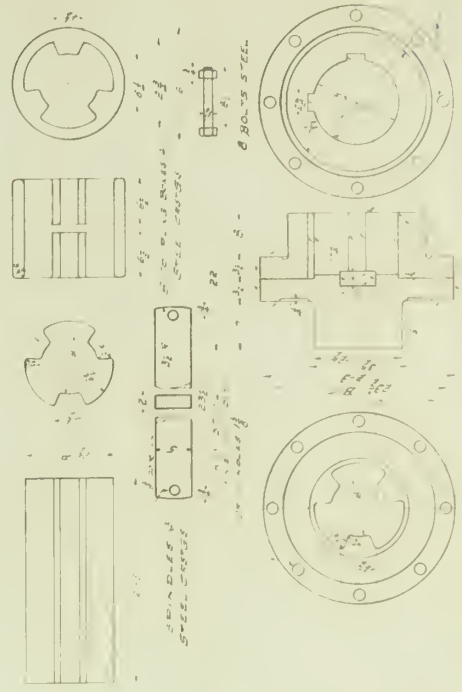
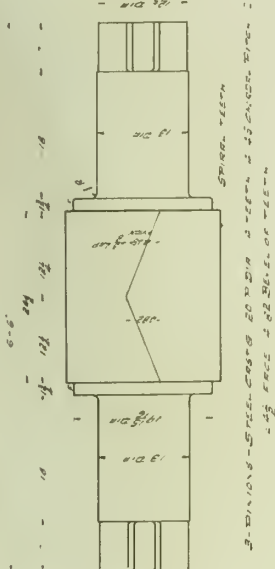
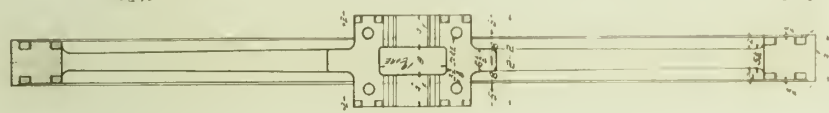
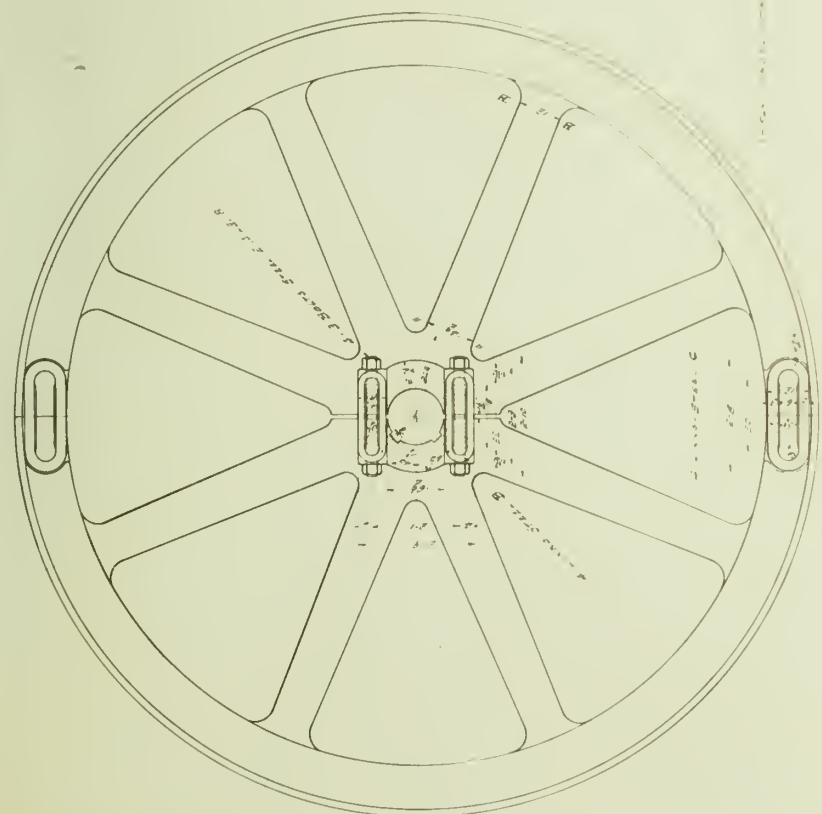


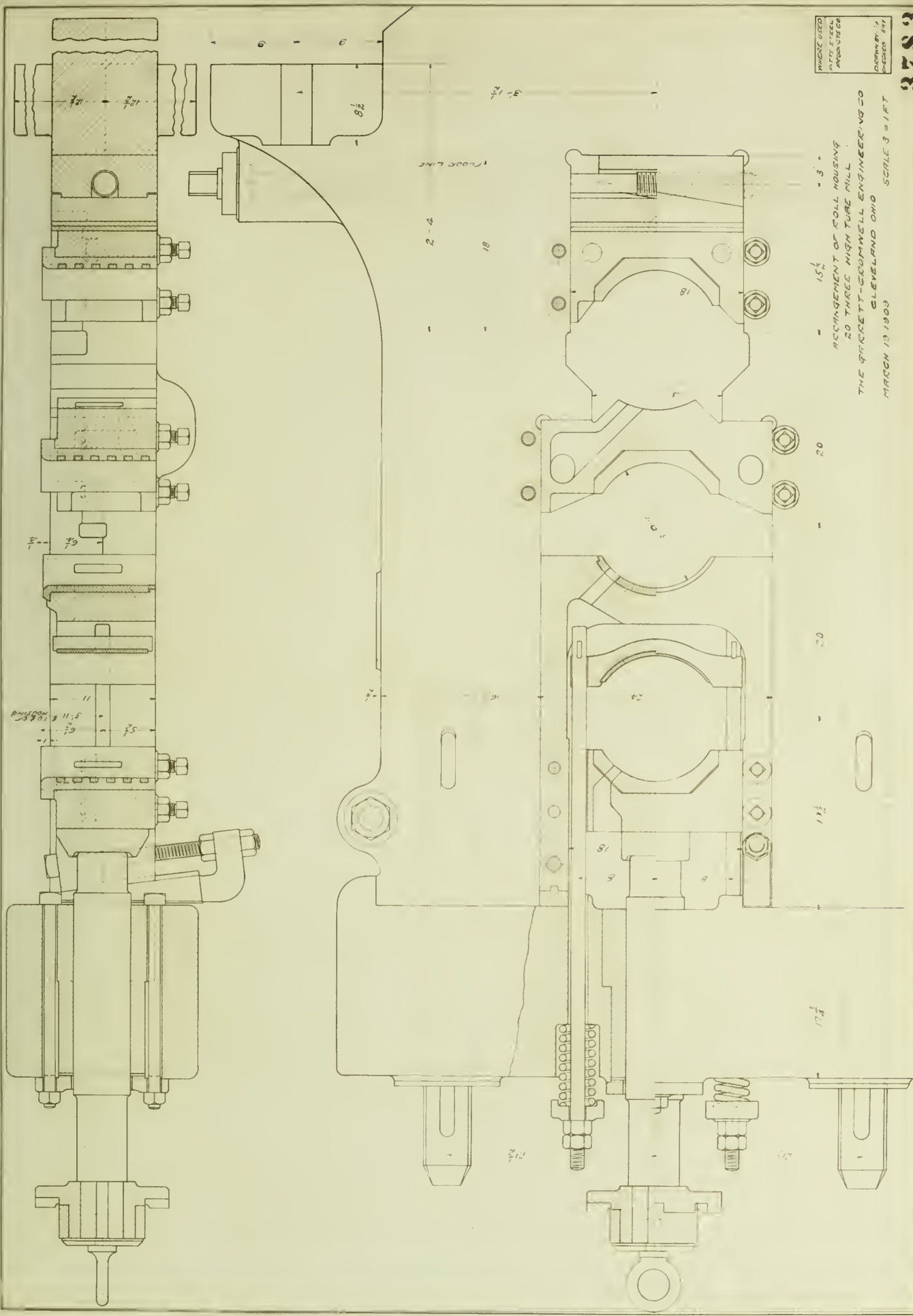
FIG. 5-22 QUARTER SECTION
ON RINGS AND IN LINES
THREE SECTORS MUST BE EXAMINED

SECTION A-A

SECTION B-B



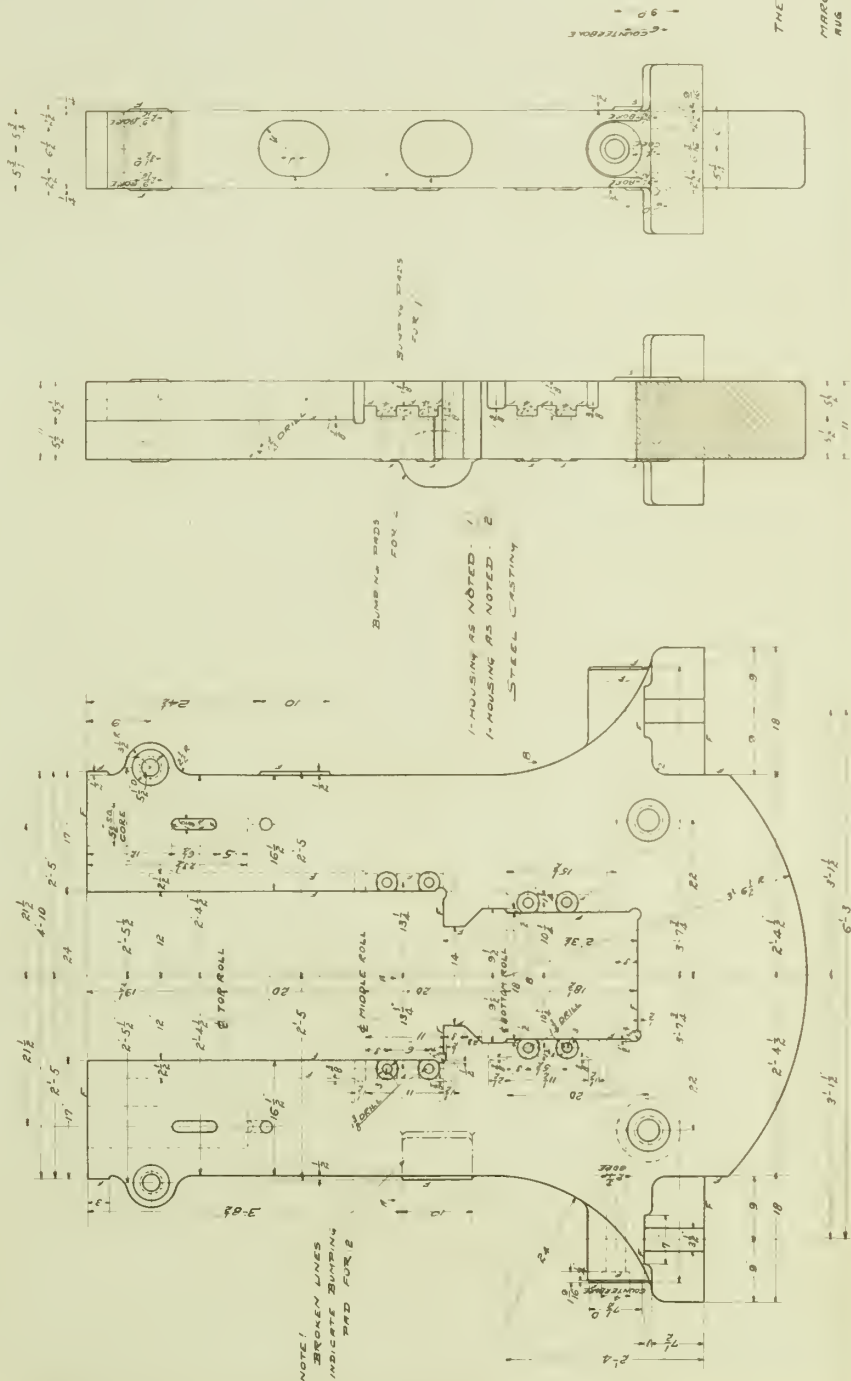
The Jackson Company
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ENGRAVERS - - PRINTERS



WHERE USED
PARTS
AND
DIMENSIONS
DRAWN BY
CHECKED BY

ARRANGEMENT OF ROLL HOUSING
FOR THREE HIGH TURRET MILL
THE GARRETT-CUMMELL ENGINEERING CO
CLEVELAND OHIO
MARCH 13 1903

3783



WHERE USED
PITTS STEEL
PRODUCTS CO.

DETAILS OF ROLL HOUSING &
RO THREE HIGH TUBE MILL
THE GARRETT-CROMWELL ENGINEERING CO.
CLEVELAND OHIO

MARCH 17, 1909
JUN 31, 1909

SCALE 1 1/2" = 1 FT

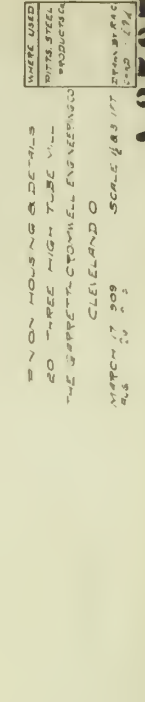
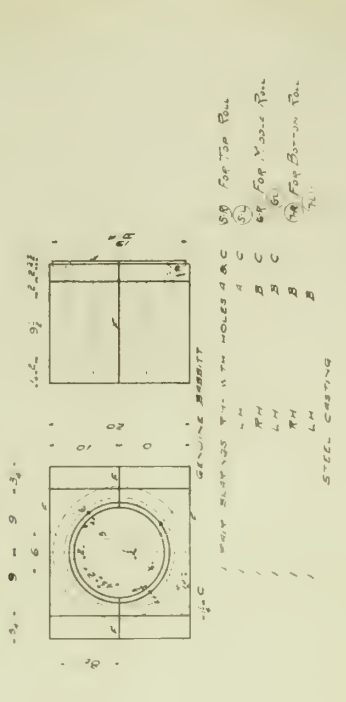
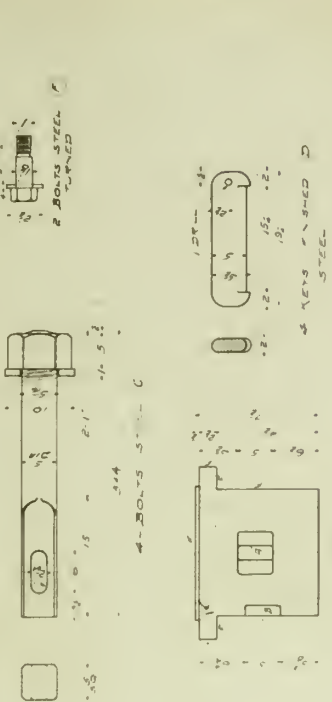
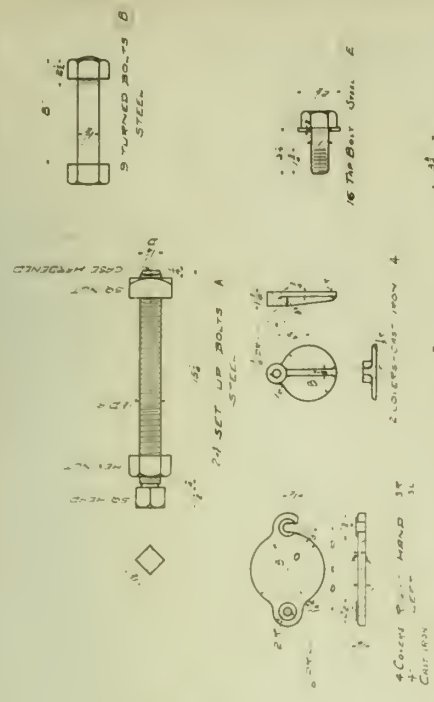
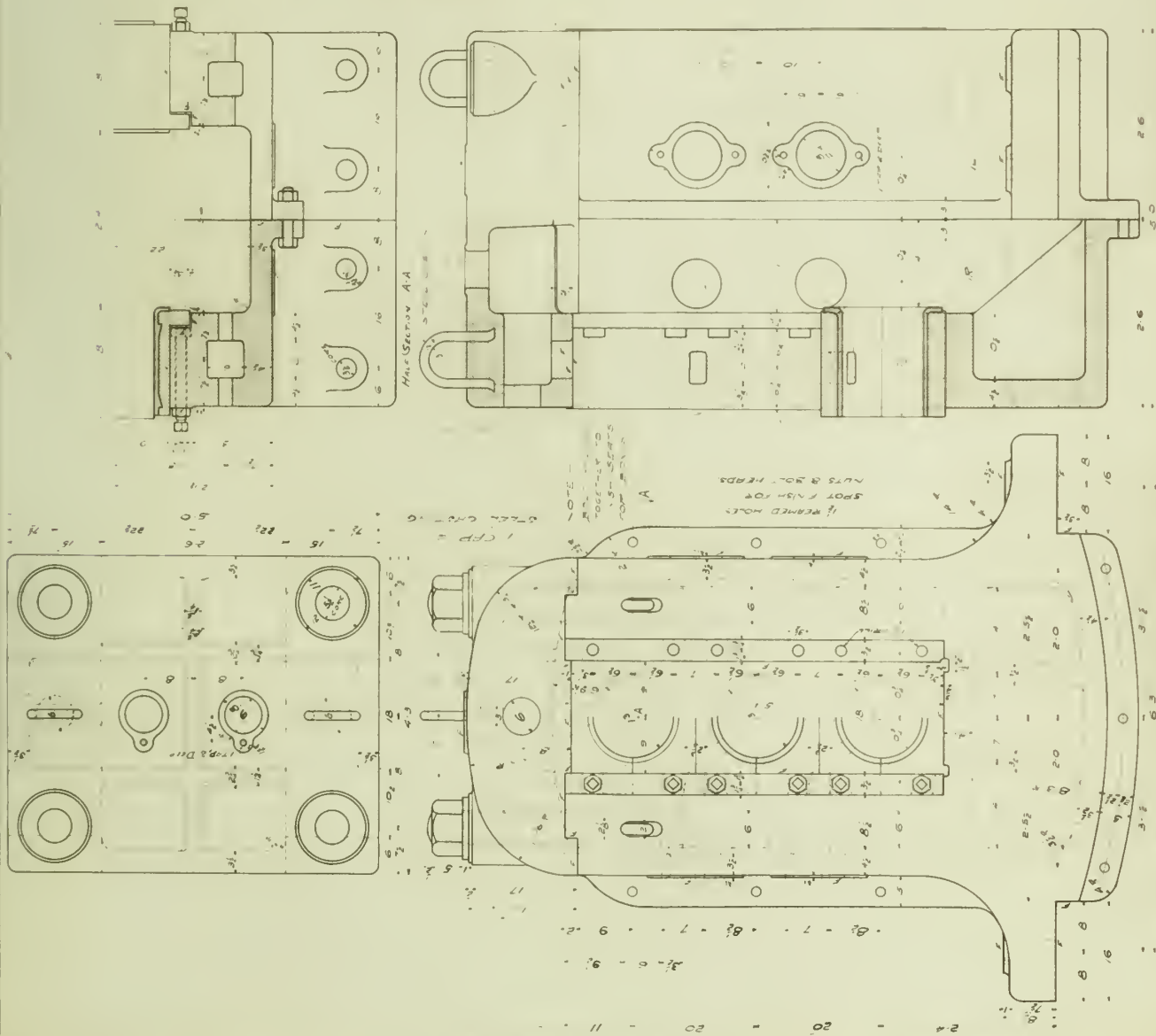
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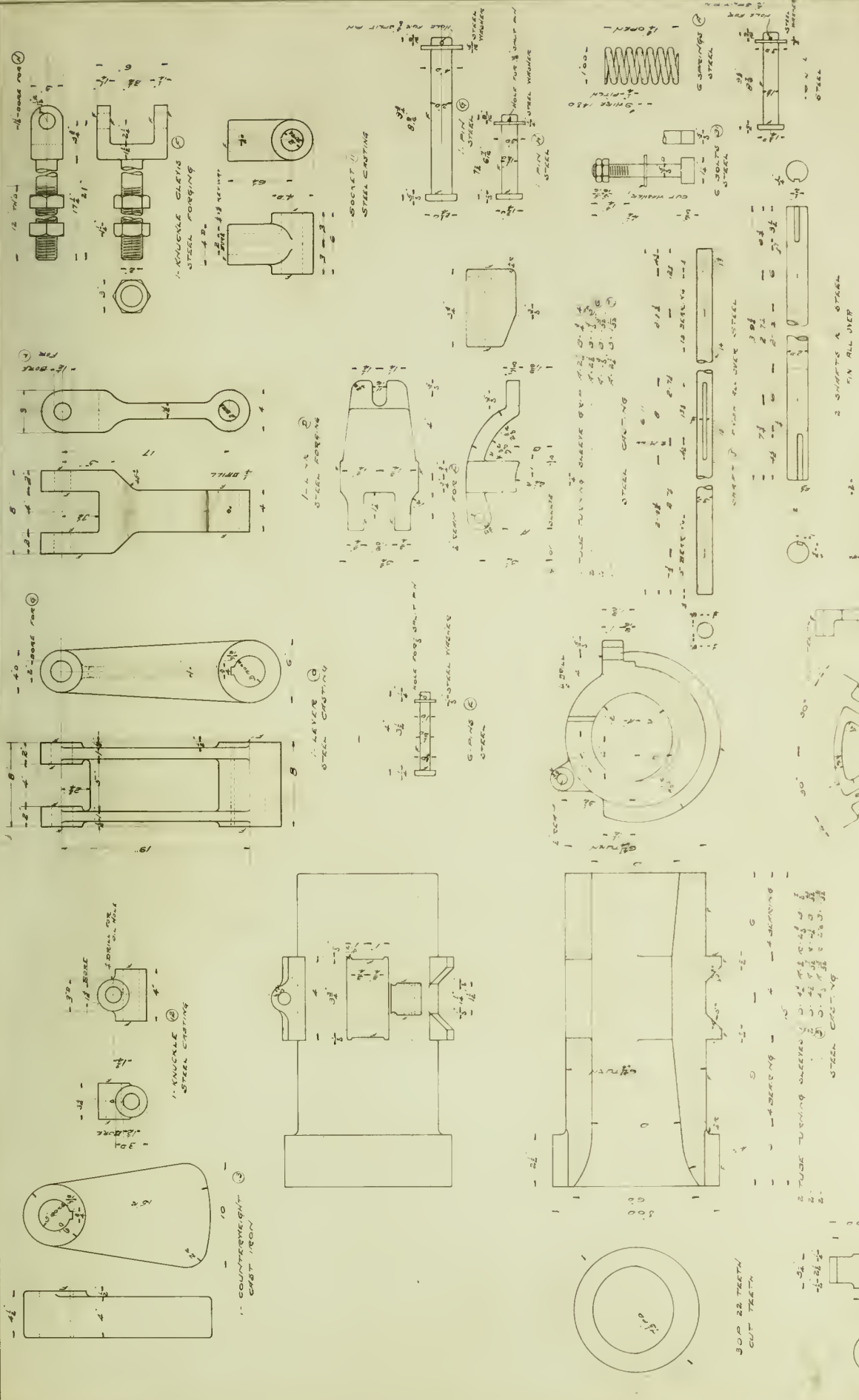
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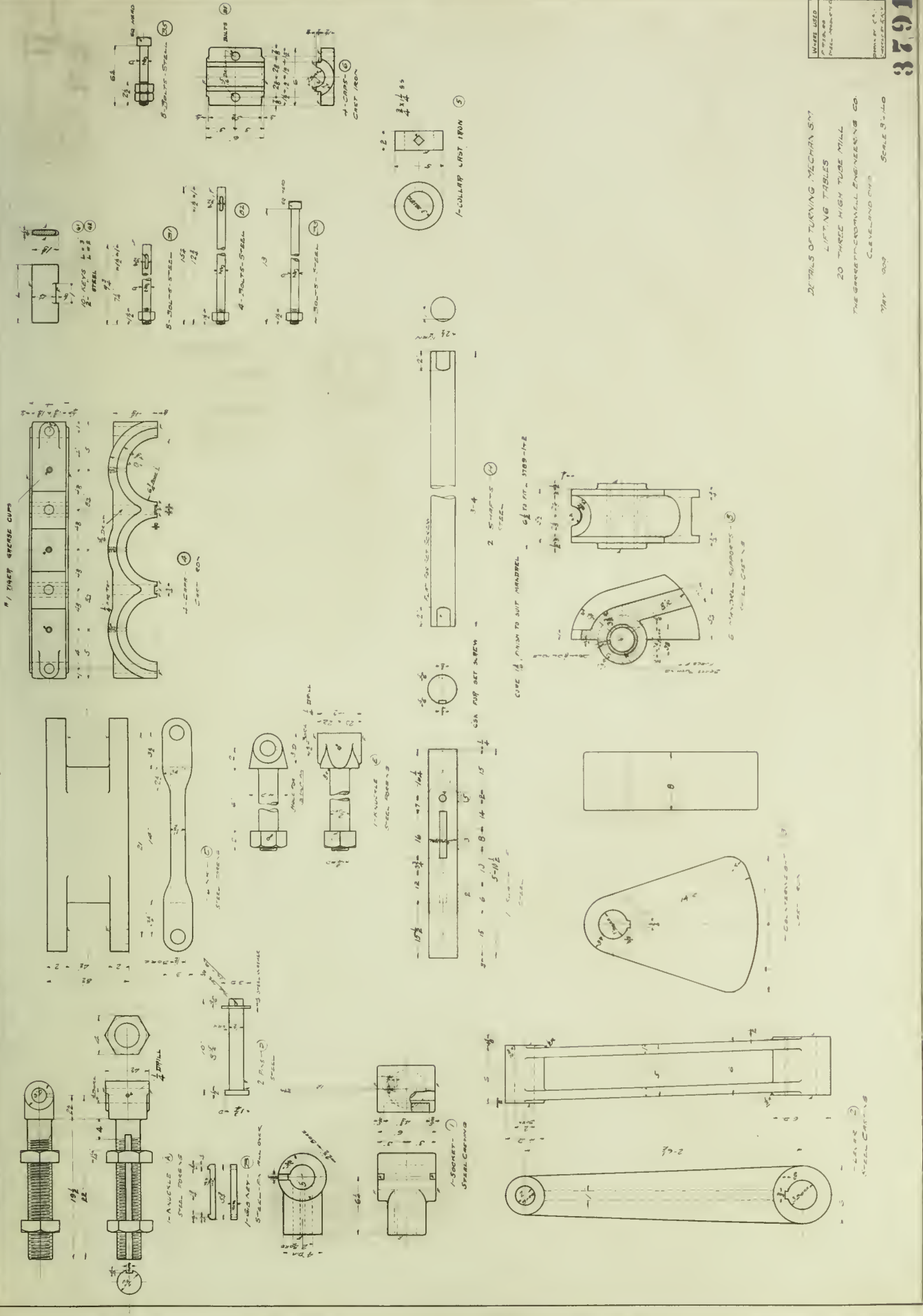
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WATER WASH
STAINLESS STEEL
RESISTANCE
WATER WASH
STAINLESS STEEL
RESISTANCE

DETAILS OF TURNING MECHANISM
LIFTING THROES
20 THREE HIGH TUBE RAIL
THE GEORGETOWN ENGINEERING CO
CLEVELAND OHIO
JAN 6 1908



DETAILS OF TURNING MACHINERY
 LIFTING TABLES
 20 THREE HIGH TUBE MILL
 THE BARRETT-CROMBIE ENGINEERING CO.
 CLEVELAND OHIO
 SCALE 3/4" = 1'-0"



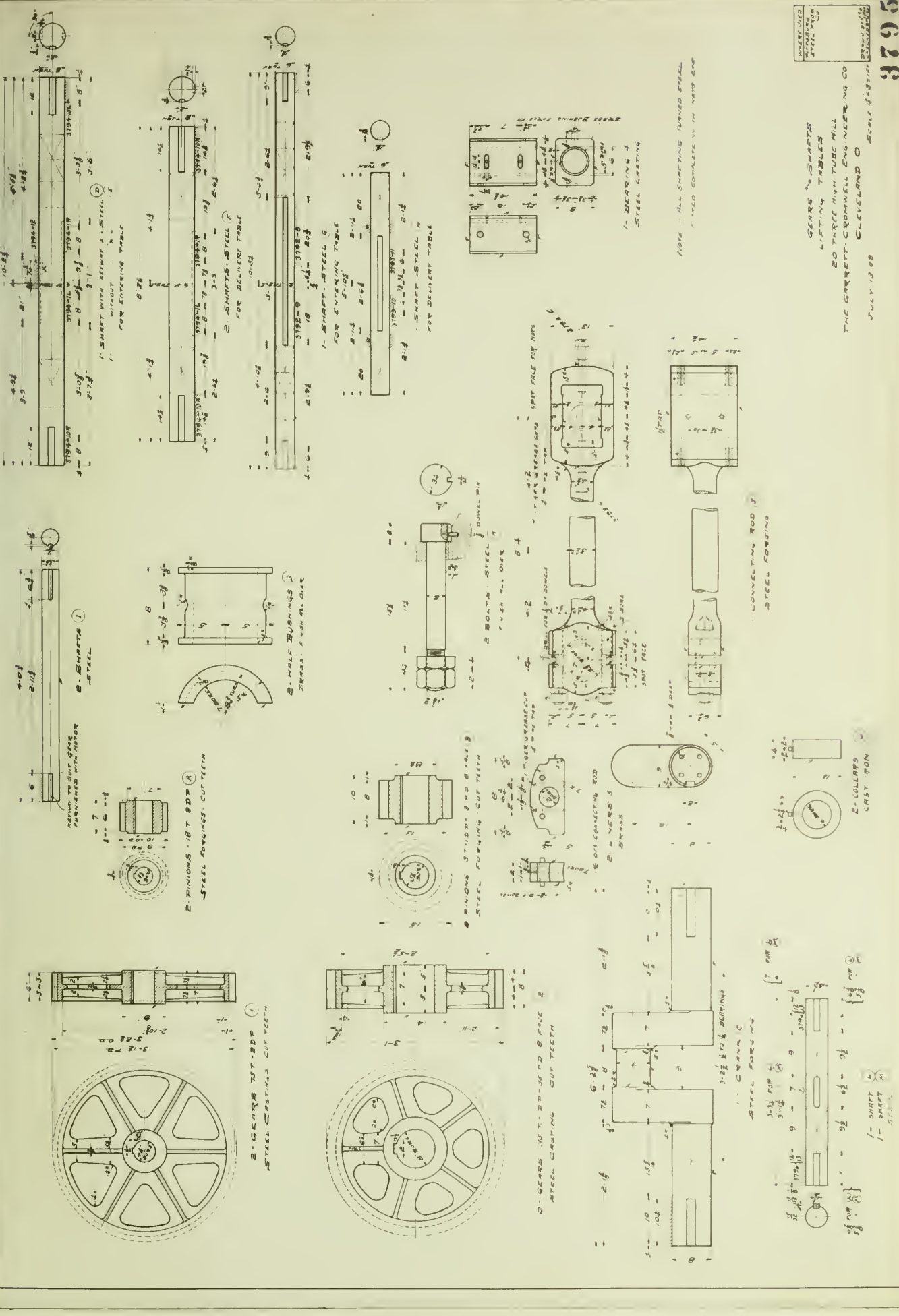


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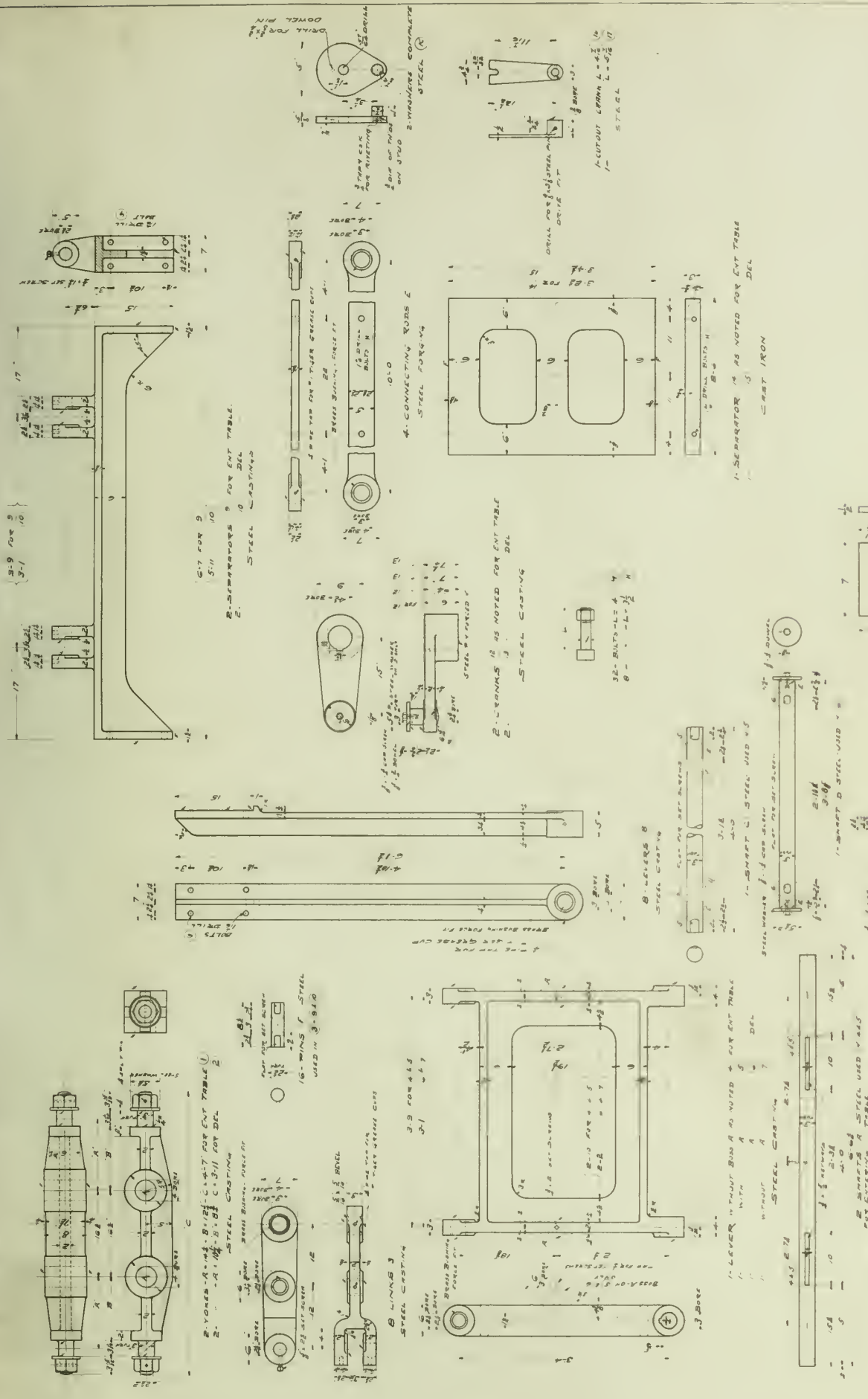


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GEARS & SHAFTS
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THE GARRETT-CROMWELL ENGINEERING CO
CLEVELAND O
JULY 1908

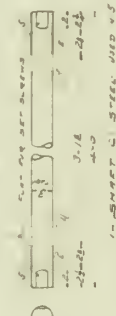


LEVERS AND SHIFTING FOR RUBBER
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THE WARRETT CLEVELAND ENGINEERING CO.
CLEVELAND, OHIO
JAN 20 1909
SCALE 1" = 1"

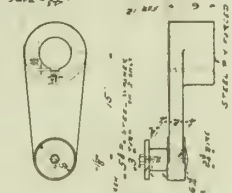


2. SHAFTS 17 AS NOTED FOR ENT. TABLE

2. COLARS 11



2. CRANKS 12 AS NOTED FOR ENT. TABLE
3. STEEL CASTING



2. SEPARATORS 9 FOR ENT. TABLE
3. STEEL CASTING



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W. L. GREENE - GREENE ENGINEERING CO.
CLEVELAND, OHIO

WHEEL SIZE 300

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Spoke 27



Spoke 26



Spoke 25



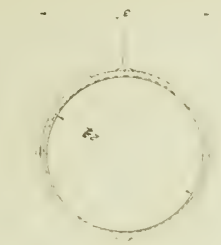
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Spoke 27



Spoke 26



Spoke 25

The Boston Company.

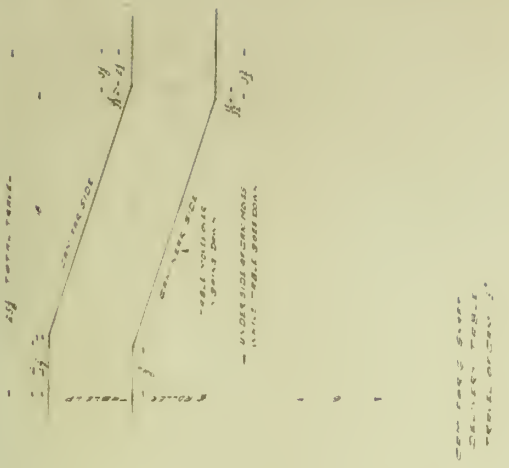
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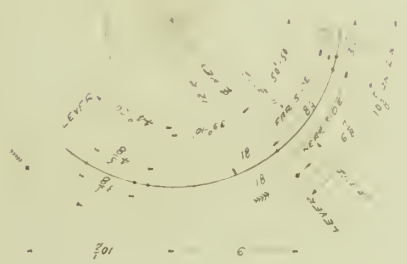


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THE BRITISH COLUMBIAN ENGINEERING CO.
VANCOUVER, B.C.



CANADIAN DIAMOND
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THE BRITISH COLUMBIAN ENGINEERING CO.
VANCOUVER, B.C.



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THE BRITISH COLUMBIAN ENGINEERING CO.
VANCOUVER, B.C.



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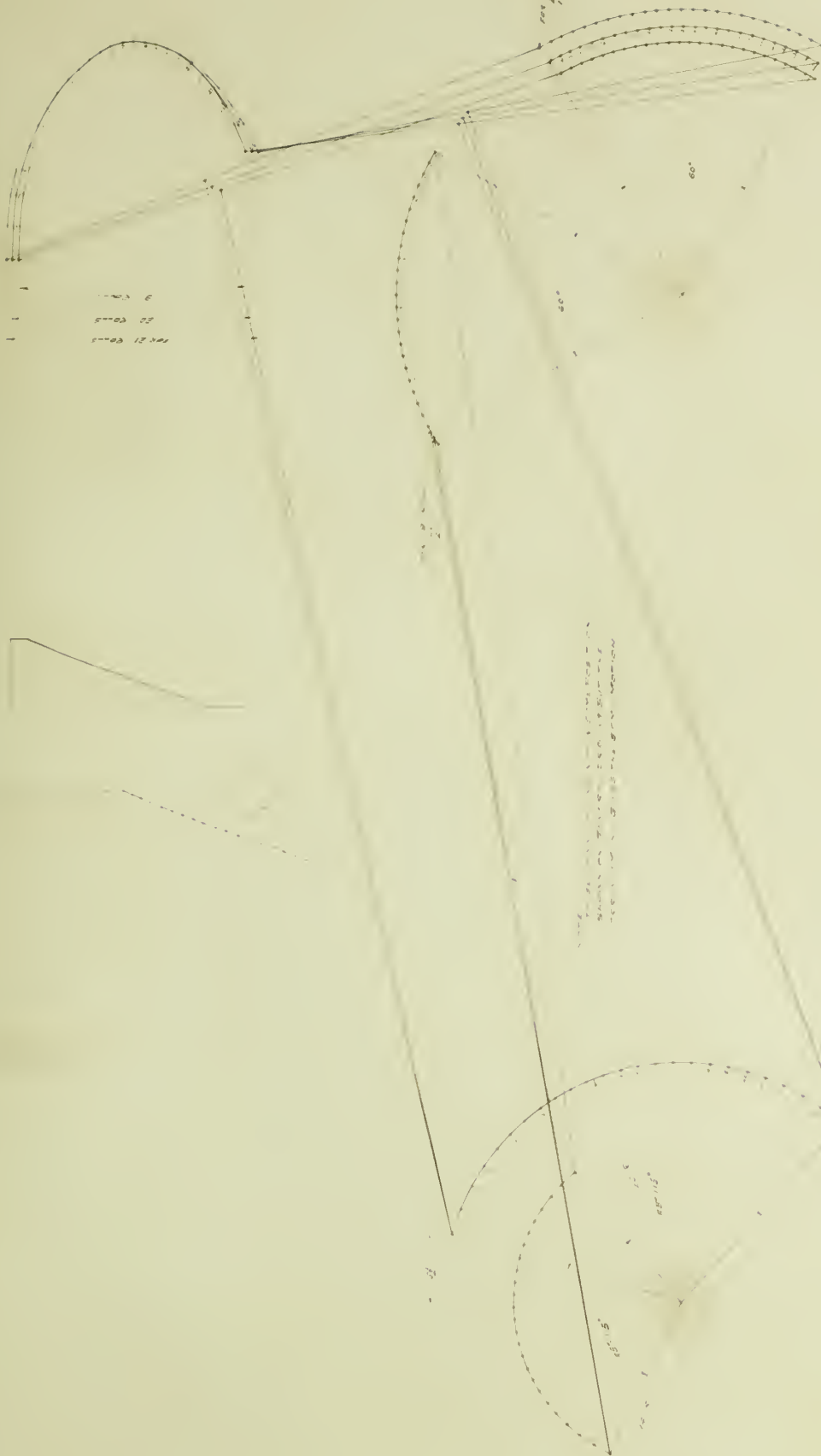
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NOTION DESIGN

DELIVERY TABLE

20 THREE HIGH TUBE M/T

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CLEVELAND OHIO

MARCH 27-1905 SERIAL 3-14

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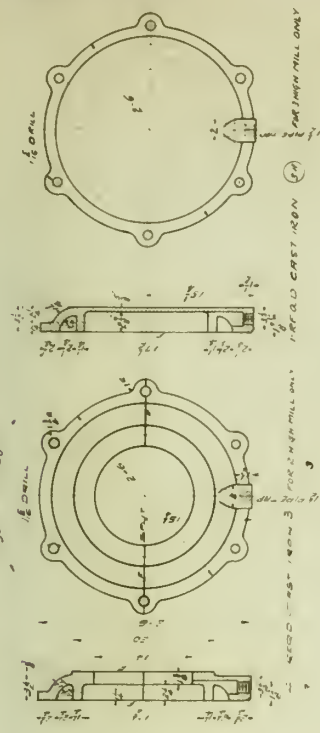


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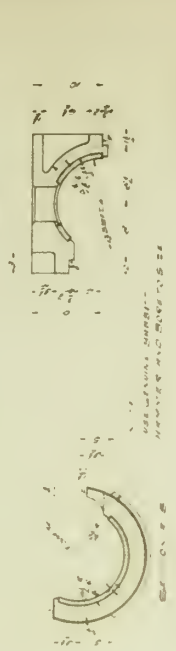
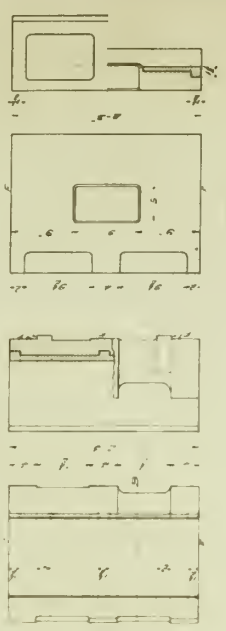
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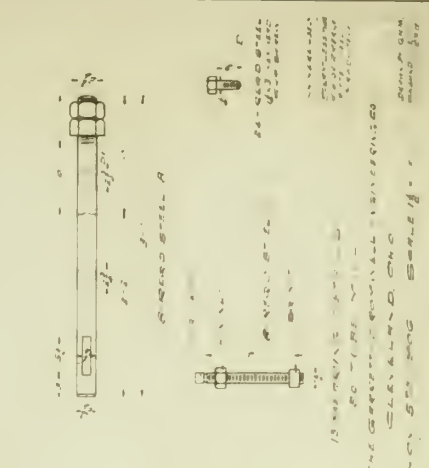
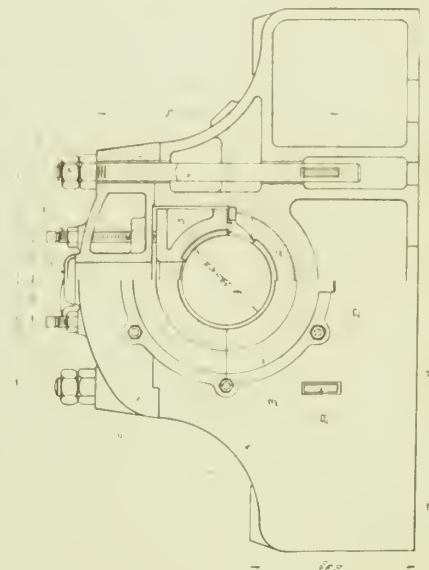
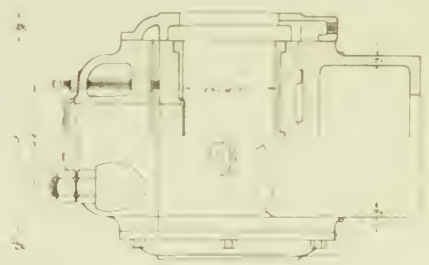
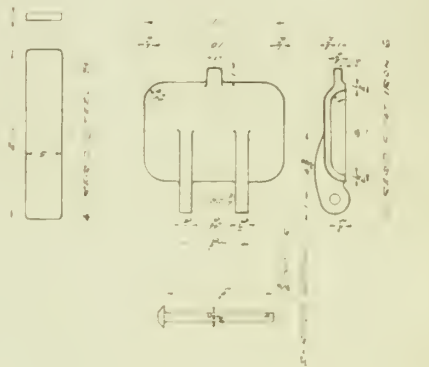
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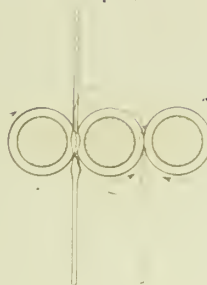
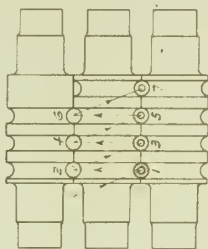
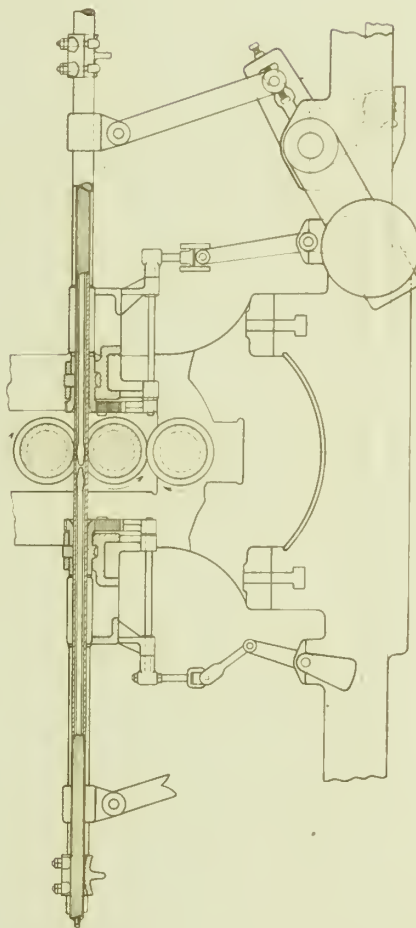


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